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Evaluation of Heavy Metals Contamination at CFAD Dundurn Resulting from Small-Arms Ammunition Incineration

S. Thiboutot
G. Ampleman
DREV, Canada

J. Lewis
S. Brochu
BCR

Defence R&D Canada

Defence Research Establishment Valcartier

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S. Thiboutot
CRDV

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Author

Sonia Thiboutot

S. Thiboutot

Approved by

Pierre Lessard

Pierre Lessard

Acting Section Head/Emerging Energetic Materials

Abstract

Disposal of surplus, obsolete, or deteriorated small arms ammunition by incineration presents the threat of heavy-metal contamination to the immediate area. The highly toxic nature of these pollutants requires that they be carefully monitored, and that steps be taken to prevent contamination altogether. The safety concerns associated with these pollutants are so serious that the United Kingdom requires stringent environmental licensing of ammunition incineration facilities, and several US states have banned the open burning of restricted materials altogether. In this context, a thorough testing of the area surrounding the small arms ammunition burning facility at CFAD Dundurn was undertaken. Groundwater, soil, and foliage from the area surrounding the burn facility were tested for the presence of heavy metals. Swab samples were taken from surfaces within the facility and these were also tested. Many of the samples showed very high levels of lead, barium, antimony, and other heavy metals. This report details the characterization of the heavy-metals contamination at CFAD Dundurn. The sampling methods are described, and the results are presented. By providing a better understanding of the nature of the problem, it is hoped that this work will help guide the Canadian Forces towards minimizing the possibly serious environmental impact of small-arms ammunition disposal.

Résumé

La destruction de munitions excédentaires, périmées et détériorées par brûlage présente un risque élevé de contamination de l`aire d`incinération par les métaux lourds. Considérant la nature hautement toxique de ces polluants, une surveillance étroite est nécessaire, ainsi que la prise de mesures afin d`éviter leur dispersion dans l`environnement. Le risque sérieux associé aux métaux lourds a conduit la Grande-Bretagne à instaurer un processus sévère de vérification environnementale de ses installations de brûlage et plusieurs États américains interdisent totalement les opérations de brûlage à ciel ouvert.

Dans ce contexte, on a décidé d`étudier la contamination par les métaux lourds causée par l`incinération de munitions de petit calibre au dépôt des Forces canadiennes de Dundurn. Une étude du site de brûlage de Dundurn a ainsi été menée par la prise d`échantillons de sol, de biomasse, d`eau souterraine et de frottis de diverses surfaces. Plusieurs échantillons montraient des concentrations nettement supérieures aux seuils acceptables de concentration de plomb, baryum, antimoine et d`autres métaux. Ce rapport fournit les détails de la caractérisation des métaux lourds effectuée à CFAD Dundurn. Les méthodes d`échantillonnage sont décrites et les résultats présentés. Ce rapport apporte une meilleure compréhension de la nature du problème associé à cette activité et aidera à guider les forces armées à minimiser l`impact environnemental négatif de la démilitarisation de ses surplus de petit calibre.

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Executive summary

Open burning/open detonation of surplus or obsolete ammunition is forbidden in some parts of the United States and is tightly regulated by the US Environmental Protection Agency (EPA) because of its potential as a source of pollution. In Britain, disposal of small arms ammunition (SAA) by incineration is tightly controlled because of the potential for lead emissions. In this context, it was decided to study the heavy-metals contamination caused by the incineration of small arms ammunition at CFAD Dundurn. This kind of environmental monitoring alerts the CF to potentially serious environmental problems before they become unmanageable. This in turn supports the policy of the Department of National Defence concerning the implementation of environmentally benign activities.

Lead is an integral component of most small-arms ammunition. Other potentially harmful metals such as antimony and cadmium are also found in CF standard ammunition. Burning these materials may lead to their dispersion in the environment. A thorough investigation of the burn site at CFAD Dundurn was conducted through the sampling of soil, water and foliage. Laboratory analysis of the samples indicated some cause for concern. While groundwater and foliage showed little contamination, soil and swab samples showed higher than acceptable concentrations of several heavy metals. These results indicate a high probability of adverse effects on human health or ecological receptors. These disturbing results should be followed up, and appropriate steps taken to correct this problem.

Moreover, an alternative method of small arms ammunition destruction, minimizing this adverse environmental impact, should be selected and implemented at CFAD Dundurn and in all other former small-arms burning locations across Canada. After the implementation of the first unit, its environmental impact should be monitored before implementing the system elsewhere.

Thiboutot, S, Ampleman, G, Lewis, J, Brochu, S. 2001. Evaluation of heavy metals contamination at CFAD Dundurn resulting from small-arms ammunition incineration. DREV TR 2001-127 Defence Research Establishment Valcartier.

Sommaire

La destruction de munitions en surplus ou dont la durée de vie a expiré, par brûlage ou détonation extérieure, est interdite dans certaines régions des États-Unis et elle est étroitement surveillée par l`organisation de protection environnementale (EPA) en raison de son potentiel comme source de pollution.

En Grande-Bretagne, la destruction des munitions de petit calibre par incinération est étroitement surveillée à cause du potentiel d`émission de plomb dans l`atmosphère. Dans ce contexte on a décidé d`étudier la contamination par les métaux lourds causée par l`incinération de munitions de petit calibre au dépôt des Forces canadiennes de Dundurn. Ce type de surveillance environnementale permet d`aviser les Forces canadiennes des problèmes sérieux avant même qu`ils ne deviennent non gérables. De plus, cette activité est en accord avec la politique du ministère de la Défense nationale sur la conduite d`activités qui minimisent l`impact environnemental.

Le plomb est un métal présent dans la plupart des armes de petit calibre. D`autres métaux lourds tels que l`antimoine et le cadmium sont également présents dans les munitions standard des Forces canadiennes. L`incinération de ces matériaux peut entraîner leur dispersion dans l`environnement. Une étude exhaustive du site de brûlage de Dundurn a ainsi été menée par la prise d`échantillons de sol, de biomasse, d`eau souterraine et de frottis de diverses surfaces.

Les résultats d`analyse des échantillons ont indiqué des problèmes. L`eau souterraine et la biomasse présentaient peu ou pas de contamination, alors que les sols ainsi que les frottis démontraient des concentrations nettement supérieures aux seuils acceptables de concentration de plusieurs métaux. Ces résultats indiquent une forte probabilité d`effets néfastes sur la santé humaine ou des récepteurs écologiques. Ces résultats inquiétants nécessitent un suivi et des actions appropriées afin de remédier à la situation. Des mesures immédiates de décontamination ont déjà été prises par le personnel du dépôt de Dundurn.

De plus, une solution de rechange alternative qui minimisera cet impact environnemental négatif devra être trouvée et remplacer le système existant à Dundurn et aux autres dépôts canadiens où le brûlage de petit calibre est nécessaire. Après l`installation de la première unité d`incinération sélectionnée, son impact environnemental devra être évalué de nouveau afin d`en assurer la sécurité environnementale avant d`en installer sur d`autres sites.

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1. Introduction

Canadian Forces Ammunition Depot (CFAD) Dundurn is located 30 km south of Saskatoon, Saskatchewan. It is the site of the largest open burning/open detonation (OB/OD) site in Canada, which prior to May 2000 incinerated nearly a million rounds of small-arms ammunition (SAA) annually. There is presently a three year accumulation of ammunition requiring disposal, due in part to a Canadian Forces-wide moratorium on small arms incineration. Prior to the instatement of the moratorium, however, SAA disposal rates lagged behind accumulation rates. The moratorium was put in place because of environmental concerns with the incineration of SAA and has made the problem worse. A new, environmentally sound burning complex of five furnaces is planned at CFAD Dundurn in order to deal with the current SAA backlog, but no suitable furnaces have yet been procured.

Small-arms ammunition comes in many different calibers. Just prior to the moratorium, the most common rounds destroyed at CFAD Dundurn were the 6.5 mm sub-caliber training insert for the 84 mm anti-tank weapon, the .50 caliber spotter/tracer round, and the 20 mm round used in the CF-18 aircraft guns. However, the OB/OD facility at CFAD Dundurn has been in operation for over 25 years, and over that time many different varieties of SAA have been disposed of including .22 cal., 9mm, 5.56mm, and 7.62mm. Such a wide variety of different rounds made mechanical disassembly of ammunition impractical. This means that the rounds were incinerated intact, with the lead-based bullet being fed into the furnace along with the brass casing and the propellant.

Most CF small arms bullets contain a 98% lead, 2% antimony alloy [1,2,3,4,5,6]. Tracer rounds contain strontium, molybdenum, and carbon tetrachloride [3,4,5,6]. The incineration of these toxic materials can understandably lead to adverse environmental impacts. If burning is not tightly controlled, temperatures may easily surpass 525° C, the point at which lead begins to vapourise. Unless a robust filtration apparatus is used to scrub such emissions, lead-contaminated particulates will be released into the environment. The furnace used to incinerate small arms ammunition at CFAD Dundurn routinely reached temperatures of 1500° F (815°C). At this temperature, lead will vapourise and be released into the environment as an airborne contaminant. The furnace also lacked any kind of scrubbing apparatus, leading to the likelihood of 25 years of lead contamination to the surrounding area.

Lead is a neurotoxic metallic element that can be absorbed by the body, primarily through the lungs and stomach. Left untreated, lead poisoning can damage many internal organs, including the kidneys, nervous system and brain [7]. The seriousness of this condition cannot be overstated.

Unlike organic pollutants such as benzene, it is not appropriate to arbitrarily ignore background levels of metals when doing environmental sampling. Metals are naturally occurring and are cycled throughout the environment by biogeochemical processes. In certain cases background levels may approach water quality standards [8]. The mere presence of a metal in a sample does not mean that the sample is contaminated. It has been reported that most non-contaminated soils contain lead concentrations of about 10– 40 µg/g. In Canada,

soil lead levels are typically about 15 μg/g [9] in the interior plains, where CFAD Dundurn is located.

This study was undertaken to assess the levels of lead and other metals in CFAD Dundurn burning facility area. Soil samples were taken from many locations within a 50 m radius of the burn site. Representative background samples were taken from two residential areas several km away from the burn site. Water samples were drawn from test wells that had been installed during earlier environmental studies [10]. Surfaces inside the building that houses the decommissioned furnace were tested for metals buildup, and samples of grass taken nearby were also tested.

This work was carried out in July 2000 following the order by the Directorate of Ammunition Program Management that immediate testing be carried out at SAA incineration installations for potential metal contamination.

2. Theory

2.1 Small arms ammunition disposal

The disposal of small arms ammunition presents a unique challenge. The destruction facility must be able to give a guarantee that all rounds processed are fully demilitarized. That is to say that they must be certified Free From Explosives [11]. This presents an obvious challenge when processing millions of live rounds. The disposal method must be 100% reliable. It must also be fast enough to cope with the rate of accumulation of ammunition.

The 1993 Canadian Forces Technical Order (CFTO) dealing with the destruction of surplus, obsolete and deteriorated ammunition [11]lists nine different ways to dispose of ammunition. These include destruction by burning, detonation, chemical decomposition, functioning and dumping at sea. Due to concerns about the environmental disruption caused by many of these methods, a Canadian Forces-wide moratorium on small arms ammunition destruction was put in place in May 2000. Prior to this moratorium, the destruction method that was used most frequently was the burning process.

Burning was authorized in one of two types of furnace: the Furnace, Ammunition Destruction, Static; or the Furnace, Ammunition Destruction, Field. Both of these furnaces are described in the 1993 CFTO [11]. The static furnace was designed for use in a permanent installation, and was the one used at CFAD Dundurn (see Fig. 1).

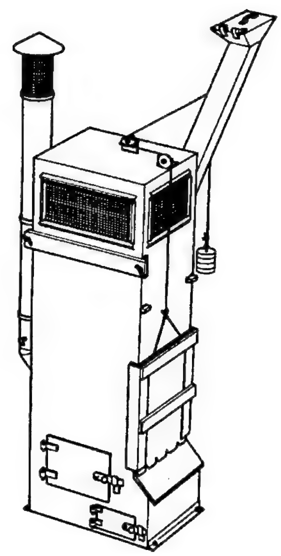

Figure 1. Furnace, Ammunition destruction, static

The field furnace was mobile and was designed for use at the unit level. It was an unsophisticated piece of equipment constructed of 1.9 cm steel plate, and fired by either

propane or oil. It was designed to allow the recovery of burned by-products e.g. brass, lead and other metal components as scrap. However, it had minimal temperature control and no emission control system. Gas emissions were released directly into the atmosphere without even a minimum of filtration. The furnace at CFAD Dundurn was in operation for over 25 years prior to the 2000 moratorium.

Although the principal lead hazard when burning small arms ammunition comes from the possibility of heating the lead bullet past its vapourization temperature, another source of small arms lead contamination should not be overlooked. All small arms ammunition includes a primer. This is a percussion sensitive explosive, which ignites the bulk propellant and fires the bullet. The primers in almost all CF ammunition include lead styphnate as an active ingredient [2,3,4,5,6], and although the primers are small, the cumulative effect of burning millions of rounds could be quite significant. As an explosive, the lead styphnate would ignite or explode in the furnace, releasing lead based gasses or particulates into the air. In other words, lead would be released into the environment regardless of whether the temperatures in the furnace were sufficient to vapourise the lead bullet.

The size of the round and its composition dictated how many could be burned at once. As a rule, the larger the round, the fewer could be burned at once. .22 mm rounds, which are very small, could be burned in batches up to 5000. Shotgun shells or 20 mm rounds could be burned in batches of 50 or less. The 20 mm round, used in the gatling-style guns of the CF-18 fighter jet, are of particular interest from a disposal point of view. Up to 1000 of these large rounds are carried on every CF-18 flight. After three flights, the rounds are declared deteriorated due to possible overpressure effects caused at altitude. These rounds are then sent for disposal. This source of deteriorated rounds places a constant demand on the SAA disposal system.

2.2 Site description – CFAD Dundurn

The SAA incineration furnace at CFAD Dundurn is housed in a three building complex (see Fig. 2). All buildings are of a utilitarian, cinder block / metal sheeting construction, single story, with flat or moderately inclined roof. The immediate surroundings consist of low shrubs and grass on flat, sandy terrain.

A work/sorting building contains the .50 cal and 20mm delinking machines, which remove the rounds from the metal belts or links prior to burning, in accordance with the 1993 CFTO [11]. It also includes storage racks and a workbench. The conveyor from the incinerator leads through this room, and it is here that the incinerated scrap is sorted. There is a single exhaust port above the scrap-sorting table.

The second building is located slightly above the other two due to a slope in the land. It is connected to the furnace building, and its uphill location is used advantageously to gravity-feed the furnace. This is accomplished through a hopper connected to a steel pipe that leads through the shared wall, downhill into the furnace. The wall that the two buildings share is of heavy concrete construction, to provide protection to workers in the case of an explosion in the furnace.

The furnace itself is located in the third building. It is positioned beneath a large double door installed flat on the roof. This is designed to provide maximum ventilation during incineration and to protect the furnace from the elements when no incineration is taking place. Of course it also allows any airborne pollutants to be released directly into the atmosphere. Incinerated rounds are removed from the furnace and dumped into metal boxes on a conveyor. This conveyor is connected to the work/sort building.

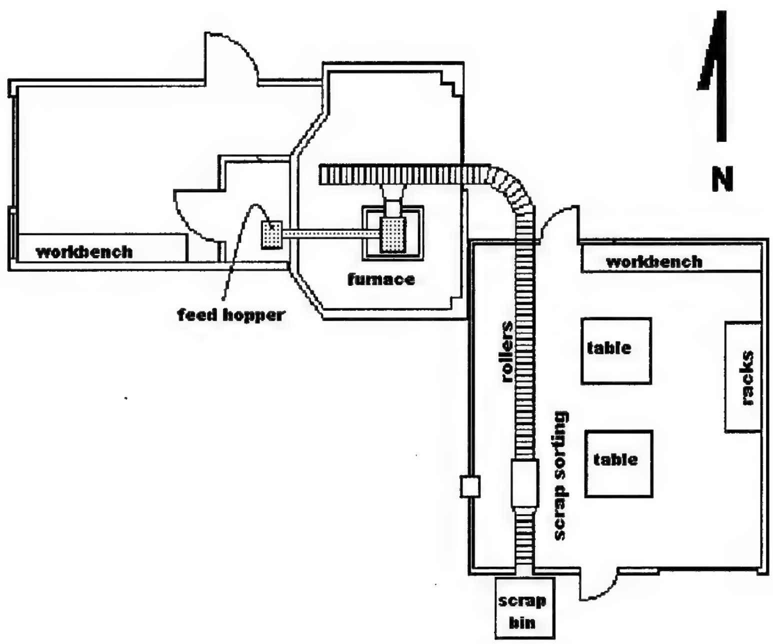

Figure 2. CFAD burn facility

One other building should be mentioned, although it is separate from the burn complex. This shelter serves as protection for personnel when explosive materials are destroyed by detonation in an open area nearby. It is approximately 100 meters away from the burn area, on the other side of an earthen berm. As the shelter is in reasonable proximity to the burn site, and is frequently used by personnel, it was included in the study.

2.3 Water samples

One of the best ways to monitor the environmental impact of a potentially contaminated site is to sample the groundwater. One of the greatest concerns at any contaminated site is that pollutants will leach into the water table and thereby spread rapidly to the surroundings. Groundwater sampling can minimize the high costs of soil sampling and analytical characterizations at large sites where systematic soil characterization can be very expensive. If contamination is detected in the groundwater, a more detailed sampling of the area can then be conducted. If no contamination is found, then it can be safely assumed that the contaminant is not seeping away from the site. This means the contamination is localized and is less of a concern.

Metal salts can be quite mobile in aqueous environments. Metal particulates, on the other hand, may be relatively immobile. The chemical form that a metal takes has a direct impact on how mobile it is likely to be. If a species is mobile in an aqueous environment, it will eventually reach the water table. If that species is toxic, as in the case of heavy metals, it can have disastrous effects on nearby populations that rely on the water table for their drinking water.

It is therefore critical to determine the size and the direction of the contamination plume in the groundwater. This is accomplished by drilling boreholes and installing observation wells to allow sampling of groundwater. A drilling firm, which specializes in contaminated site assessment, must be employed to install wells at different depths according to the depth of the groundwater table. Proposed boreholes must be located according to local geology, topography, and the presumed direction of groundwater flow. Hydrogeologists should be consulted to evaluate both groundwater flow direction and the likely size of the groundwater plume. There are very specific procedures relating to the installation of observation wells [12]. Once installed, a protective well casing should cover the well.

2.4 Soil samples

Soil samples have the drawback of being quite heterogeneous. That is to say, samples taken from within several meters of each other may show a difference of several orders of magnitude in the concentration of contaminants. This means that the representativeness uncertainties frequently far exceed the inherent collection and analysis uncertainties. Often it is not possible to quantify the analyte concentration uncertainties associated with the sample selection. In these instances, qualitative descriptions of the uncertainties due to sampling limitations should be clearly described and the associated assumptions documented.

In most cases, this uncertainty requires that some form of sample compositing be done. Sample compositing is the mixing of several samples taken from a local area in order to obtain a representative reading of the contaminants present. Compositing can be done in many different ways. Unique soil samples may be taken in several locations, and then mixed

to obtain a composite sample. Another option is to remove all the surface soil from a well-defined area or line and mix the resulting mass thoroughly. The danger in compositing is that peak values may be diluted. If peak concentrations are a concern, rather that average concentrations, composite samples must be supplemented with discrete samples in order to identify the worst-case concentrations of the analytes of interest.

The most common changes in soil samples are volatile loss, biodegradation, oxidation, or reduction. While these don't usually play a role when dealing with metal contaminants, there are exceptions. Sample degradation should be assumed to be a possibility, and the possibility minimized by sealing samples in glass containers immediately after the samples are taken, with as little headspace as possible. The samples should also be refrigerated until analysis, and the samples analyzed as soon as possible [13].

2.5 Swab sampling

Swab sampling is performed to determine how much pollution residue or contamination is present on a surface. Surfaces may become contaminated following contact with airborne or liquid pollutants. As such, buildings, equipment and work areas may become contaminated over time. Both interior and exterior surfaces are at risk.

In general, surfaces are tested by wiping with an inert, absorbent material that has been saturated with a solvent. While the shape of the surface area is not critical (the test surface may be isolated as a circle, rectangle or square etc.), being able to determine the precise area of the test surface is very important. This information later allows calculation of concentration per unit area. The surface area tested is usually in the range of 400 to 900 cm^2[14]. The outline of the area being studied should be measured carefully with a ruler or compass, and then delineated with a masking agent.

The sampling material may be cotton gauze, Q-tips, or clean filter paper. The choice of material depends on the surface area to be tested, its physical condition, and the concentration of contaminant. Q-tips are more suitable to small surfaces, while cotton gauze lends itself to larger dimensions or surfaces with oily residue requiring a considerable capacity for absorption.

The most common solvents used for swab sampling are purified water and hexane, used for inorganic and organic solvents respectively. Both will slowly dissolve a large number of pollutants without affecting the substrate. Pollutants that are strongly attached to the substrate can usually be removed with the friction of wiping. It is therefore fairly rare that more aggressive solvents are needed [14].

When sampling, the surface should be wiped in a consistent fashion – either horizontally or vertically. Going over the same surface twice should be avoided. The sampling material or tissue used should be dampened with the solvent of choice, avoiding saturation. If required, more solvent may be added to the tissue with an eyedropper. As sampling progresses, the sampling material may be folded when it appears saturated with the contaminant. Another option is to use several pieces of the tissue. Once soiled, the samples should be handled as little as possible to avoid loss of material. The contaminated samples should be immediately

placed in an amber glass container in the case of organic substances, and a plastic or glass container for inorganic substances. The acceptable limit for surface contamination by lead is 50 mg/m^2, according to the Quebec Ministry of the Environment. This works out to be 4500 $\mu g/900\ cm^2$, which corresponds to the area tested by the swab samples.

2.6 Foliage samples

Local plants (foliage) can be used as an indicator for how pollution is affecting an ecosystem. Unless a pollutant enters the local biomass, it is of little concern from a biological point of view. Plants accumulate lead in relation to the lead content of the soil [15,16,17]. However, fixation of soluble lead by organic matter often occurs in the humus soil layer, reducing the amount of soluble lead available for uptake by the plants. Plant lead concentrations can be considerably lower than soil lead concentrations. Lead concentrations in lettuce, beets, cabbage, and carrots were found to be only 1– 8% of the concentration of lead in soil [16,17]. Lead is absorbed mainly by root hairs and is stored in the cell walls, and evidence indicates that translocation of lead to aboveground tissues does not readily occur [18]. Soil pH and redox potential are the most important variables determining plant uptake of lead [19]. Raising pH (liming) and the addition of organic matter to soils reduce the uptake of lead in plants [20,21]; however, the eventual decomposition of the organic complex may again release lead into the soil solution.

Very few studies have examined the concentrations of lead in plants in relation to sites that have experienced high deposition of lead. For plants on shooting ranges, where lead is deposited as shot, the highest concentrations of lead were found in the roots, with decreasing concentrations in the leaves and fruit [22]. Foliage from three plant species contained quantities of lead that were elevated over levels in control area plants. Lingonberries (*Sorbus aucuparia* and *Vaccinium vitis-idaea*) collected at the clay target shooting range contained lead concentrations up to 0.3 mg/kg wet weight (ww), which exceeded Finland's Food Safety Guidelines. Mushrooms (*Russula* spp.) exhibited lead concentrations of 4 mg/kg ww, 10-fold higher than the average for *Russula* spp.

If foliage contains a pollutant, that substance has entered the local food chain, and represents a risk. While there are currently no accepted threshold criteria for heavy metals in biomass, it has been demonstrated that as contaminants move up the food chain, they become more concentrated. While levels of a given toxin in plants may be quite low, the animals that feed on those plants will display higher concentrations as those toxins collect in body tissues. Carnivores feeding on the herbivores will in turn display even higher concentrations of the pollutant. Ultimately, at the top of the food chain, distressingly high levels of toxins may cause serious physical effects. This bioaccumulation of environmental pollutants has been well documented and must be carefully considered when sampling biological systems [23].

3. Experimental

3.1 Sampling methods

All samples were obtained in July 2000 from the open burning facility at CFAD Dundurn. Specifics concerning each sample type are given below.

3.1.1 Water samples

Water samples were taken from 27 locations. 26 of the samples were drawn from wells drilled for a previous study. The 27th sample was taken from surface water present in a crater formed by an open detonation near well P3. Groundwater samples were drawn by a mechanical pump following a 30-minute purge time, and were stored in 500 ml amber glass jars prior to shipment to Envirolab for analysis.

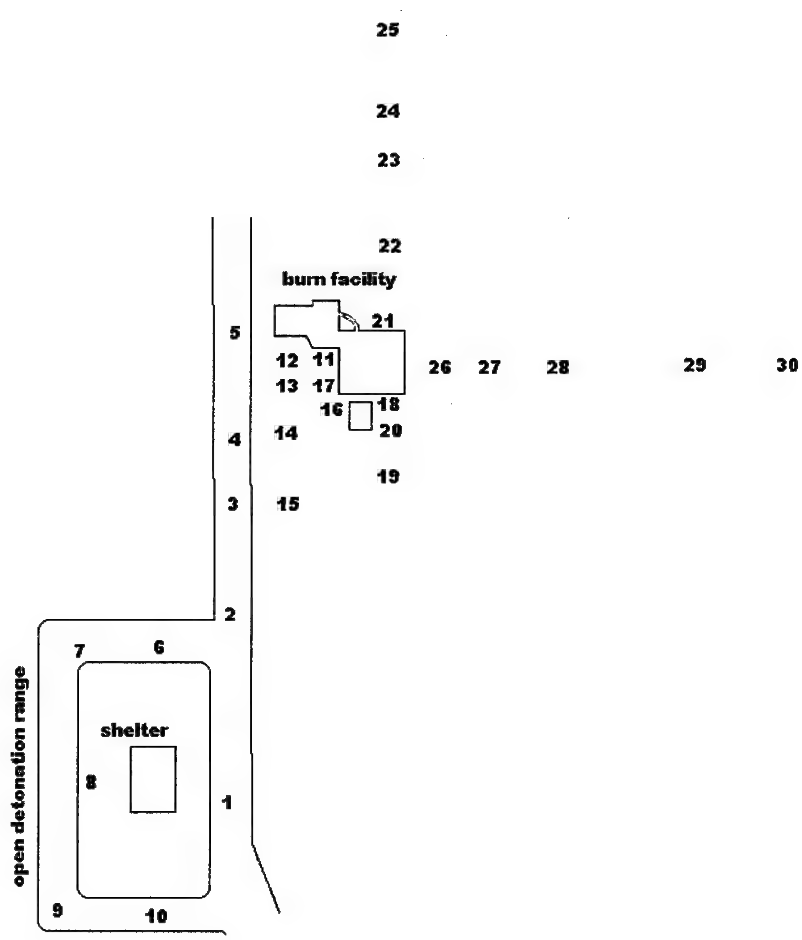

Figure 3. Soil sample locations

3.1.2 Soil samples

Soils samples were taken using two different compositing techniques. The locations of the soil samples are shown in Fig 3. Numbers correspond to the soil sample number.

The first method of compositing is shown in Fig 4. It is a method that was originally developed to test for energetic materials [24], but may be used for most composite sampling applications. Seven discrete samples, corresponding to the numbers shown in the diagram, are taken using a stainless steel auger. The auger diameter is 5 cm. Originally this method consisted of collecting samples in a circular pattern with a diameter of 122 cm. 6 samples were taken from the circumference, equidistant to one another, and the seventh sample was taken from the center of the circle. These samples are then thoroughly mixed to obtain a representative

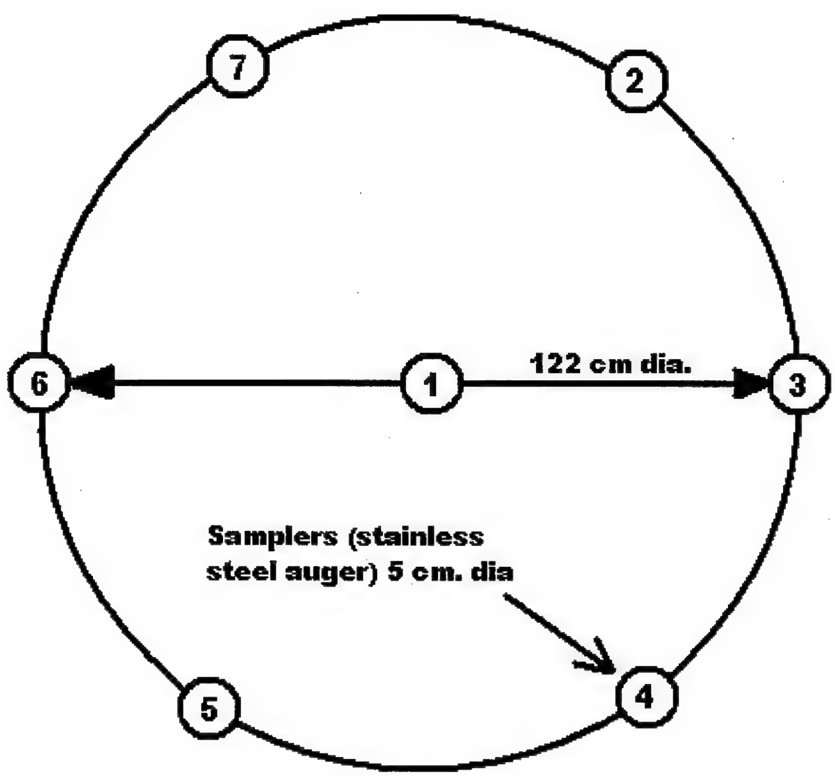

Figure 4. Soil compositing grid

composite sample. For the purposes of this study, this protocol was modified. A 5 cm deep layer of soil was scraped from the entire area covered by the 122 cm diameter circle. The resulting pile of earth was thoroughly mixed before a representative sample was taken.

The second method of compositing was to measure out a linear distance of either 6 or 10 meters, and take 20 discrete samples along this line, equidistant to each other. These 20 discrete samples were then mixed to obtain the representative sample. Annex 1 lists which method of compositing was used to obtain each sample, and also gives sample locations.

Samples were sealed in polyethylene bags for transportation to Envirolab of Sainte Foy Quebec, where the analysis was conducted. Samples were refrigerated from the time they were taken until analysis.

3.1.3 Swab samples

35 swab samples were taken. A 30 cm by 30 cm template was laid on the surface to be sampled, and the outline delineated with masking tape. Small medical-type cotton gauze swabs were dampened with distilled water and wiped horizontally over the sample area.

Fresh swabs were used once the old ones were saturated with contaminant. Swabs were stored in sealed glass jars until analysis. Fig. 5 and 6 show the 35 locations where swab samples were taken at the burn facility and shelter respectively.

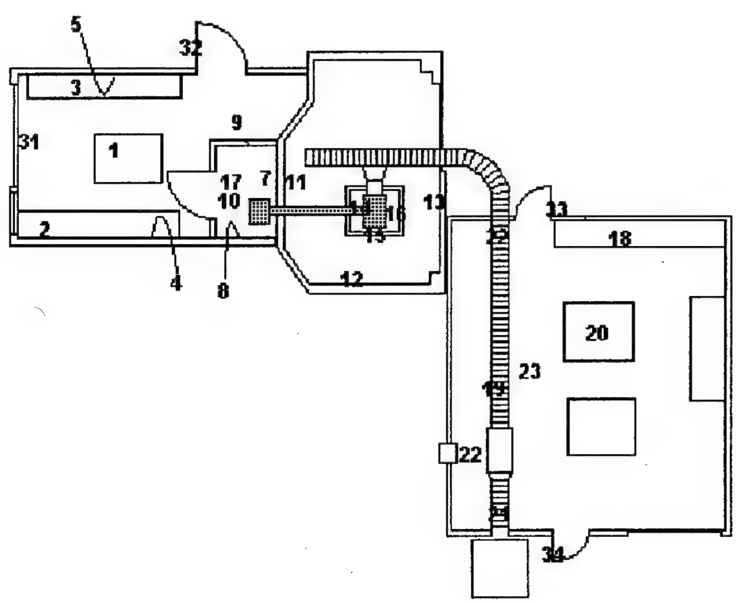

Figure 5. Burn facility swab locations

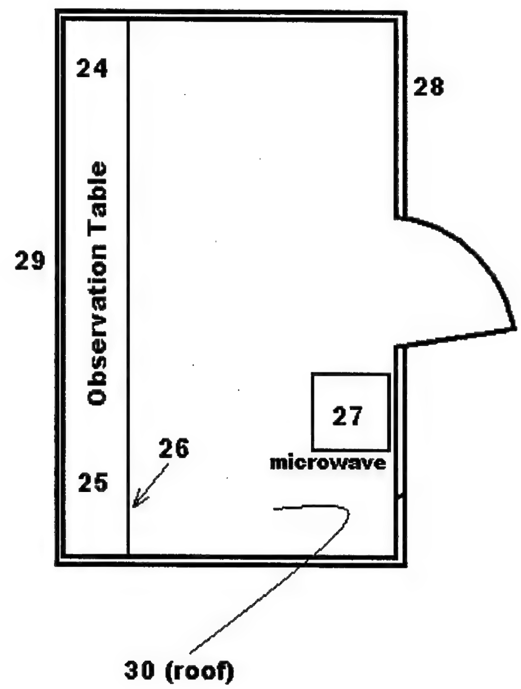

Figure 6. Shelter swab sample locations

3.1.4 Foliage samples

Four representative foliage samples were obtained by compositing. Each sample of grass leaves and stems was collected randomly over a 0.5 km^2 area. The four samples were collected in one of four broad locations, located to the northeast, northwest, southeast and southwest of the burn facility and shelter. These locations may be seen in Fig 7. The sample to the NE was collected on the large earthen berm located at the site. A compositing approach was used and a minimum of 20 discrete samples were collected randomly over the 0.5 km^2 area. The foliage samples were each approximately 1 kg total, and were stored in several large polyethylene bags. Samples were frozen and sent to the lab where they were totally digested prior to analysis.

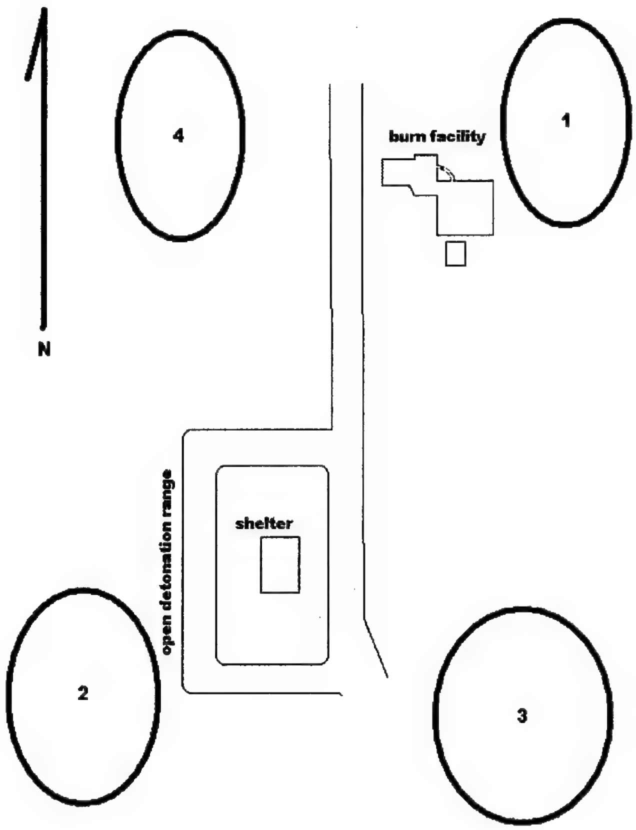

Figure 7. Foliage sampling locations

3.2 Sample analysis and contractors

Laboratory analysis of all samples was conducted by Envirolab, a division of de Roche ltée, Sainte Foy, Quebec, under the supervision of Bernard Montminy, M.Sc. The samples were tested for the presence of 36 discrete elements, including lead, chromium, barium, antimony and boron.

4. Results and discussion

Acceptable Canadian limits for concentrations of contaminants in soil and water, and surfaces were obtained from several sources [25,26]. These limits are the maximum allowable concentrations before an object is declared dangerous by Canadian standards. A copy of all limits may be viewed in Tables 1, 2 and 3. The United States EPA has recently adopted very stringent standards in relation to levels of lead found in paint, dust and soil. For purposes of comparison, these standards will be given following Tables 2 and 3.

Table 1. *Remediation criteria for water*

ELEMENT	FRESHWATER AQUATIC LIFE (mg/L)	IRRIGATION (mg/L)	LIVESTOCK WATERING (mg/L)	DRINKING WATER (mg/L)
Aluminum	0.005-0.1	5	5	---
Barium	---	---	---	1
Beryllium	---	0.1	0.1	---
Boron	---	0.5-6	5	5
Cadmium	0.0002-0.0018	0.01	0.02	0.05
Calcium	---	---	1000	---
Chromium	0.002-0.02	0.1	0.001	0.05
Cobalt	---	0.05	1	---
Copper	0.002-0.004	0.2-1	0.5-5	≤1
Iron	0.3	5	---	≤0.3
Lead	0.001-0.007	0.2	0.1	0.01
Manganese	---	0.2	---	≤0.05
Molybdenum	---	0.01-0.05	0.5	---
Nickel	0.025-0.15	0.2	1	---
Silver	0.0001	---	---	---
Vanadium	---	0.1	0.1	---
Zinc	0.03	1-5	50	≤5

Table 2. *Interim remediation criteria for soil*

ELEMENT	AGRICULTURAL (mg/kg)	RESIDENTIAL/ PARKLAND (mg/kg)	COMMERCIAL/ INDUSTRIAL (mg/kg)
Antimony	20	20	40
Barium	750	500	2000
Beryllium	4	4	8
Boron	2	---	---
Cadmium	3	5	20
Chromium	750	250	800
Cobalt	40	50	300
Copper	150	100	500
Lead*	375	500	1000
Molybdenum	5	10	40
Nickel	150	100	500
Silver	20	20	40
Thallium	1	---	---
Vanadium	200	200	---
Zinc	600	500	1500
** US EPA standards: 400 mg/kg in children's play areas, 1200 mg/kg other residential*			

4.1 Groundwater sample results

The results of the groundwater analyses may be found in Annex 1. In general, there is nothing alarming about any of the tested parameters. In nearly all cases, the actual concentrations of the elements tested for are lower than the detection limits of the analytical methods. The only exception to this is the sample of surface water taken at P3. This sample shows elevated readings of several elements including lead.

It should be pointed out that in several cases, the acceptable limits are actually below laboratory detection limits. Lead, chromium, copper, molybdenum, and zinc are examples. For instance, the maximum recommended concentration of dissolved lead is 7 μg/L, or .007mg/L in the case of water in freshwater wetlands. This is in contrast with the detection limit of 0.1 mg/L. In other words, while the lead concentrations may be at or below detection limits, they may still be an order of magnitude above acceptable environmental concentrations.

Table 3. Quebec ministry of the environment criteria for surface contamination

ELEMENT	CRITERIA	
Column 1 subheading	***mg/m²***	***µg/900 cm²***
Barium	1000	90 000
Boron	5000	450 000
Cadmium	5	450
Chromium	50	4500
Lead*	50	4500
** US EPA standards: 40 µg/900 cm² floors, 250 µg/900 cm² walls*		

4.2 Soil sample results

The soil samples showed some elevated readings. All results may be viewed in Annex 2. The sandblast residues from the furnace, samples S-39A and S-39B were heavily contaminated, with lead concentrations an order of magnitude above acceptable values for industrial sites. These samples also had barium and copper levels three orders of magnitude above acceptable levels and cadmium concentrations 4 times higher than acceptable. Other elements were also found in elevated concentrations, such as strontium, phosphorus and zinc. Considering the nature of the samples, these results are not surprising.

Other soil samples were not as toxic as the sandblast residue, but some still showed alarmingly high levels of lead. S-11, S-12, S-16, S-17, and S-21 all showed very high lead levels, with concentrations up to 10 times higher than the acceptable limits. S-11, S-16, S-21 and S-27 all were higher than the allowable industrial limits for antimony, with S-21 also being above the allowable limits for barium and copper.

Fortunately, these results appear relatively localized. Soil samples taken from residential areas both on and off the base (S-31 and S-32) showed lead concentrations comfortably within the typical normal range of soils of 2-300 mg/kg. Furthermore, measured concentrations of lead decreased rapidly with increasing distance from the burn facility. The difference in lead levels in samples S-12 to S-15 or in samples S-26 to S-29 demonstrate this clearly.

4.3 Swab sample results

The swab samples were a cause for serious concern. Several samples taken in work areas showed astronomically high lead concentrations. The maximum allowable concentration of lead in a 900 cm^2 area is 40 μg on floors or 250 μg on walls or windowsills according to the most recent standards published by the US EPA. Twenty-seven of the 35 swab samples were above this limit. Complete results may be viewed in Annex 3. Seven of these, FR 10, FR-11, FR-17, FR-18, FR-21 and FR-22, were several orders of magnitude higher than the acceptable limits as put forth by both the EPA and the Quebec ministry of the environment (see Table 3). These samples were taken inside the buildings of the burn facility, which were used routinely by personnel. It should be pointed out that the criteria listed in Table 3 are the values at which objects are sufficiently contaminated to be considered hazardous materials. The seven samples listed were effectively over 100 times higher than these limits.

Lead was not the only contaminant of concern. Other metals were also found to be well above acceptable limits. Samples FR-10, FR-17, FR-18, FR-21, FR-22 and FR-35 also showed very high concentrations of barium, up to 30 times acceptable values. High levels of cadmium showed up in 4 samples, FR-3, FR-10, FR-17 and FR-20, the latter being nearly 10 times above the government standard. FR-1 showed elevated levels of chromium.

Several other metals such as strontium, zinc, molybdenum, manganese, and aluminum were found in very high concentrations in several of the samples. However, there are no published values concerning maximum acceptable values for these elements. These elements have, however, been shown to be toxic in some environments, and their presence here should not be overlooked.

4.4 Foliage sample results

The results of the four composite foliage samples seem, initially, to be acceptable. Annex 4 lists the analytical results from the foliage samples. Lead concentrations are quite low when compared to most of the soil samples. However, considering that Bisessar and McIlveen [16,17] determined that terrestrial plant uptake of lead was 1-8% of the soil concentrations, even these low values are of concern. They become more alarming when one considers that Fleming found little lead migration to aboveground plant tissues – most lead remained concentrated in the roots. The foliage samples taken in this study were exclusively aboveground – stems and leaves. No roots were sampled. Strontium, barium, and boron were also found at levels that may be cause for concern, although no published criteria exist for the presence of these elements in terrestrial plants.

Prevailing winds at CFAD Dundurn are northeasterly. Therefore it would be expected that composite sample 1 would show the highest levels of contamination, while sample 2 could be considered a background sample. However, no such trend is

evident in the results. Only lead is significantly higher in sample 1 than in the other three samples.

It should also be pointed out that this study involved the complete digestion of the biomass sample prior to analysis, and therefore cannot differentiate between lead that was bioaccumulated and that which was deposited as dust on the surface of the plants. Should another study be conducted, both acid digestion and leachates should be conducted in order to give more detailed information. As well, a more representative background sample should be collected at a greater distance from the OB/OD site.

As was pointed out above, the bioaccumulation of contaminants moving up the food chain is well documented. The presence of these metals in or on foliage indicates that local animals may have considerable concentrations of lead and other metals in their systems, with all of the physical problems that this leads to. This is of particular concern seeing how deer hunting is allowed at CFAD Dundurn. In theory, if these deer are consumed as food, high levels of metals could be absorbed by humans.

5. Conclusions and recommendations

The open burning facility at CFAD Dundurn has been contaminated with heavy metals by a quarter century of small arms ammunition incineration. Localized contamination appears in some cases to be quite severe as indicated by the foliage, soil and swab samples. However, there does not appear to be any transport of contaminants into the water table, and hence the contamination appears to be contained. This conclusion is further supported by soil samples taken at residential areas several kilometers away from the burn facility, which showed normal background levels for all metals.

The obvious recommendation of ceasing all small arms ammunition burning has already been put into place by the CF nation-wide, not just at CFAD Dundurn. The second obvious recommendation of installing an environmentally friendly small arms ammunition disposal system complete with scrubbers and filters is currently being pursued by the CF. It is possible to destroy small arms ammunition without incinerating, as has been demonstrated by the Defence Research and Evaluation Agency (DERA) in the UK. DERA have had success in destroying small arms ammunition using an obsolete tire shredder called a cracker mill, and this very environmentally friendly procedure should be considered by the CF.

It is also recommended that further testing be done to determine the precise extent of the lead contamination to the surrounding soil, and that this soil be treated or disposed of accordingly. The shelter and burn facility buildings must be thoroughly cleaned and painted to ensure the safety of workers.

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Annex 1 – Locations and sampling patterns for soil samples

SAMPLE	METHOD	LOCATION	SAMPLE	METHOD	LOCATION
S-1	Circular Pattern	2m E of shelter entrance	S-21	Linear, 10 m wide, 20 sub-samples	Sorting area roof runoff, N
S-2	Circular Pattern	18m N of sample 1	S-22	Linear, 10 m wide, 20 sub-samples	10m N of sorting area
S-3	Circular Pattern	30m N of sample 1	S-23	Linear, 10 m wide, 20 sub-samples	20m N of sorting area
S-4	Circular Pattern	39m N of sample 1	S-24	Linear, 10 m wide, 20 sub-samples	30m N of sorting area
S-5	Circular Pattern	50m N of sample 1	S-25	Linear, 10 m wide, 20 sub-samples	40m N of sorting area
S-6	Circular Pattern	13m N of shelter	S-26	Linear, 6 m wide, 20 sub-samples	3m E of sorting area
S-7	Circular Pattern	12m NW of shelter	S-27	Linear, 6 m wide, 20 sub-samples	8m E of sorting area
S-8	Circular Pattern	8m W of shelter	S-28	Linear, 6 m wide, 20 sub-samples	16m E of sorting area
S-9	Circular Pattern	12m SW of shelter	S-29	Linear, 6 m wide, 20 sub-samples	30m E of sorting area
S-10	Circular Pattern	13m S of shelter	S-30	Linear, 6 m wide, 20 sub-samples	40m E of sorting area
S-11	Circular Pattern	1m S of furnace room, 1m W of sorting area	2-31	Circular Pattern	Private land – Maj. Brownrigg
S-12	Circular Pattern	1m S of furnace room, 4m W of sorting area	S-32	Circular Pattern	Private land – 304 4th St. Dundurn

SAMPLE	METHOD	LOCATION	SAMPLE	METHOD	LOCATION
S-13	Circular Pattern	6m S of furnace room, 4m W of sorting area	S-33	Circular Pattern	Composite of circle drive
S-14	Circular Pattern	11m S of furnace room 4m W of sorting area	S-34	Circular Pattern	Composite of open burning area
S-15	Circular Pattern	19m S of furnace room 4m W of sorting area	S-35	Circular Pattern	Composite of open burning area
S-16	Circular Pattern	6m S of furnace room, 1m W of sorting area	S-36	Circular Pattern	Composite of circle drive (NW and NE)
S-17	Circular Pattern	6m S of furnace room, 2m W of sorting area	S-37	Circular Pattern	Composite of circle drive, (SW and SE)
S-18	Linear, Width of Garage Door	3m S of sorting area garage door	S-38	Circular Pattern	Composite, access road
S-19	Linear, Width of Garage Door	11m S of sorting area garage door	S-39a	Discrete Sample	Incinerator sandblast sample
S-20	Linear, Width of Garage Door	4m S of sorting area garage door	S-39b	Discrete Sample	Incinerator sandblast sample

Annex 2 - Analytical results of groundwater

	Descrip.	Sb	Ag	Al	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Eu	Fe	Ga	Ge	K	La	Li
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg
BL		< 0.1	<0.010	0,1	<0.13	<0.030	<0.1	0,036	0,835	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,397	<0.1	<0.2	0,09	<0.1	<0
CRM		0,5	0,386	143	0,91	3,82	<0.1	0,359	1190	0,14	0,2	<0.1	0,365	5,1	<0.003	131	<0.1	<0.2	57,5	0,1	0,1
242072	P1A	< 0.1	<0.010	0,02	<0.13	0,395	<0.1	<0.001	72,8	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,034	<0.1	<0.2	1,99	<0.1	<0
242073	P1B	< 0.1	<0.010	0,04	<0.13	0,54	<0.1	0,016	80,8	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,015	<0.1	<0.2	1,37	<0.1	<0
242074	P2A	< 0.1	<0.010	0,02	<0.13	0,424	<0.1	0,019	76,8	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,039	<0.1	<0.2	1,88	<0.1	<0
242075	P2B	< 0.1	<0.010	0,05	<0.13	0,378	<0.1	0,046	84,2	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,053	<0.1	<0.2	1,94	<0.1	<0
242076	P3A	< 0.1	<0.010	0,02	<0.13	0,731	<0.1	0,06	129	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,002	<0.1	<0.2	2,04	<0.1	<0
242077	Sur.P3	< 0.1	<0.010	4	<0.13	0,364	<0.1	0,019	18,3	0,024	<0.1	<0.1	<0.030	0,5	<0.003	4,14	<0.1	<0.2	11,8	<0.1	<0
246367	P4A	< 0.1	<0.010	0,02	<0.13	0,346	<0.1	0,02	70,4	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,071	<0.1	<0.2	2,03	<0.1	<0
242079	P4B	< 0.1	<0.010	0,02	<0.13	0,474	<0.1	0,048	98,8	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	2,06	<0.1	<0.
242080	P6A	< 0.1	<0.010	0,01	<0.13	0,364	<0.1	0,023	78,2	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	2,08	<0.1	<0.
242081	P6B	< 0.1	<0.010	0,009	<0.13	0,618	<0.1	0,02	97,4	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,06	<0.1	<0.
242082	P7A	< 0.1	<0.010	0,02	<0.13	0,464	<0.1	0,027	73,5	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,011	<0.1	<0.2	1,88	<0.1	<0.
242083	P7B	< 0.1	<0.010	0,01	<0.13	0,127	<0.1	0,018	69	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,52	<0.1	<0.
242084	P8A	< 0.1	<0.010	0,01	<0.13	0,459	<0.1	0,034	76,5	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,72	<0.1	<0.
242085	P8B	< 0.1	<0.010	0,01	<0.13	0,354	<0.1	0,021	82,5	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,002	<0.1	<0.2	1,47	<0.1	<0.
242086	P9	< 0.1	<0.010	0,02	<0.13	0,373	<0.1	0,009	80,2	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,7	<0.1	<0.
242087	P10	< 0.1	<0.010	0,2	<0.13	0,582	<0.1	0,007	93,9	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,426	<0.1	<0.2	2,74	<0.1	<0.
242088	P11	< 0.1	<0.010	0,01	<0.13	0,488	<0.1	0,031	77,7	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,006	<0.1	<0.2	1,56	<0.1	<0.
242089	P12A	< 0.1	<0.010	0,05	<0.13	0,392	<0.1	0,03	83,1	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,119	<0.1	<0.2	1,99	<0.1	<0.
242090	P12B	< 0.1	<0.010	0,03	<0.13	0,53	<0.1	0,056	86,7	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,45	<0.1	<0.
242091	P13A	< 0.1	<0.010	0,02	<0.13	0,386	<0.1	0,026	77,5	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,008	<0.1	<0.2	1,75	<0.1	<0.
242092	P13B	< 0.1	<0.010	0,02	<0.13	0,487	<0.1	0,021	74,8	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,75	<0.1	<0.
242093	P14A	< 0.1	<0.010	0,008	<0.13	0,394	<0.1	<0.001	74,4	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,009	<0.1	<0.2	2,14	<0.1	<0.
242094	P14B	< 0.1	<0.010	0,02	<0.13	0,439	<0.1	0,045	70,6	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	1,61	<0.1	<0.
242095	P15A	< 0.1	<0.010	0,004	<0.13	0,197	<0.1	0,036	52,4	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,016	<0.1	<0.2	2,11	<0.1	<0.
242096	P15B	0,13	<0.010	0,01	<0.13	0,404	<0.1	0,017	102	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	<0.001	<0.1	<0.2	2,07	<0.1	<0.
242097	P16	< 0.1	<0.010	0,01	<0.13	0,399	<0.1	0,011	78,1	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,015	<0.1	<0.2	2	<0.1	<0.
242098	P17	0,14	<0.010	0,03	<0.13	0,335	<0.1	0,027	75,4	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0,0978	<0.1	<0.2	1,83	<0.1	<0.

	Ga	Ge	K	La	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sc	Sm	Sr	Th	Ti	V	Y	Zn
-	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
7	<0.1	<0.2	0,09	<0.1	<0.030	0,055	<0.030	<0.1	0,137	<0.030	<0.1	<0.1	<0.030	<0.030	<0.030	<0.1	0,004	<0.1	<0.030	0,2
	<0.1	<0.2	57,5	0,1	0,111	60,2	1,87	0,2	23,7	0,295	107	0,9	<0.030	0,034	6,77	<0.1	3,6	1,1	0,098	6,6
4	<0.1	<0.2	1,99	<0.1	<0.030	14,2	0,328	<0.1	4,46	<0.030	<0.1	<0.1	<0.030	<0.030	0,238	<0.1	0,001	<0.1	<0.030	<0.1
5	<0.1	<0.2	1,37	<0.1	<0.030	14,4	<0.030	<0.1	3,99	<0.030	<0.1	<0.1	<0.030	<0.030	0,15	<0.1	0,002	<0.1	<0.030	<0.1
9	<0.1	<0.2	1,88	<0.1	<0.030	14,1	0,54	<0.1	4,36	<0.030	<0.1	<0.1	<0.030	<0.030	0,228	<0.1	0,001	<0.1	<0.030	<0.1
3	<0.1	<0.2	1,94	<0.1	<0.030	14,9	0,046	<0.1	4,29	<0.030	<0.1	<0.1	<0.030	<0.030	0,225	<0.1	0,005	<0.1	<0.030	<0.1
2	<0.1	<0.2	2,04	<0.1	<0.030	24,3	<0.030	<0.1	8,66	<0.030	<0.1	<0.1	<0.030	<0.030	0,292	<0.1	0,002	<0.1	<0.030	<0.1
	<0.1	<0.2	11,8	<0.1	<0.030	4,1	0,314	<0.1	2,5	<0.030	0,3	0,3	<0.030	<0.030	0,406	<0.1	0,02	0,1	<0.030	0,4
1	<0.1	<0.2	2,03	<0.1	<0.030	13,8	0,332	<0.1	4,4	<0.030	<0.1	<0.1	<0.030	<0.030	0,247	<0.1	0,002	<0.1	<0.030	<0.1
01	<0.1	<0.2	2,06	<0.1	<0.030	17,8	0,296	<0.1	3,93	<0.030	<0.1	<0.1	<0.030	<0.030	0,266	<0.1	0,001	<0.1	<0.030	<0.1
01	<0.1	<0.2	2,08	<0.1	<0.030	16,9	0,546	<0.1	5,01	<0.030	<0.1	<0.1	<0.030	<0.030	0,263	<0.1	0,001	<0.1	<0.030	<0.1
01	<0.1	<0.2	1,06	<0.1	<0.030	18	<0.030	<0.1	4,07	<0.030	<0.1	<0.1	<0.030	<0.030	0,18	<0.1	0,002	<0.1	<0.030	<0.1
1	<0.1	<0.2	1,88	<0.1	<0.030	13,6	0,314	<0.1	4,1	<0.030	<0.1	<0.1	<0.030	<0.030	0,195	<0.1	0,004	<0.1	<0.030	<0.1
01	<0.1	<0.2	1,52	<0.1	<0.030	21,2	<0.030	<0.1	6,1	<0.030	<0.1	<0.1	<0.030	<0.030	0,32	<0.1	0,002	<0.1	<0.030	<0.1
01	<0.1	<0.2	1,72	<0.1	<0.030	13,7	0,355	<0.1	4,4	<0.030	<0.1	<0.1	<0.030	<0.030	0,188	<0.1	<0.001	<0.1	<0.030	<0.1
2	<0.1	<0.2	1,47	<0.1	<0.030	13,2	<0.030	<0.1	4,51	<0.030	<0.1	<0.1	<0.030	<0.030	0,214	<0.1	<0.001	<0.1	<0.030	<0.1
01	<0.1	<0.2	1,7	<0.1	<0.030	15,6	0,615	<0.1	4,34	<0.030	<0.1	<0.1	<0.030	<0.030	0,212	<0.1	0,001	<0.1	<0.030	<0.1
6	<0.1	<0.2	2,74	<0.1	<0.030	14,8	0,468	<0.1	4,67	<0.030	<0.1	<0.1	<0.030	<0.030	0,243	<0.1	0,0097	<0.1	<0.030	<0.1
6	<0.1	<0.2	1,56	<0.1	<0.030	15,6	0,563	<0.1	3,86	<0.030	<0.1	<0.1	<0.030	<0.030	0,2	<0.1	0,001	<0.1	<0.030	<0.1
9	<0.1	<0.2	1,99	<0.1	<0.030	14,8	0,654	<0.1	7,15	<0.030	<0.1	<0.1	<0.030	<0.030	0,187	<0.1	0,004	<0.1	<0.030	<0.1
01	<0.1	<0.2	1,45	<0.1	<0.030	14,7	<0.030	<0.1	4,69	<0.030	<0.1	<0.1	<0.030	<0.030	0,176	<0.1	0,001	<0.1	<0.030	<0.1
8	<0.1	<0.2	1,75	<0.1	<0.030	13,6	0,427	<0.1	4,32	<0.030	<0.1	<0.1	<0.030	<0.030	0,269	<0.1	0,002	<0.1	<0.030	<0.1
001	<0.1	<0.2	1,75	<0.1	<0.030	19,7	0,194	<0.1	4,27	<0.030	<0.1	<0.1	<0.030	<0.030	0,214	<0.1	0,002	<0.1	<0.030	<0.1
9	<0.1	<0.2	2,14	<0.1	<0.030	15,8	0,522	<0.1	4,87	<0.030	<0.1	<0.1	<0.030	<0.030	0,319	<0.1	0,001	<0.1	<0.030	<0.1
001	<0.1	<0.2	1,61	<0.1	<0.030	14,4	0,168	<0.1	4,15	<0.030	<0.1	<0.1	<0.030	<0.030	0,226	<0.1	0,001	<0.1	<0.030	<0.1
6	<0.1	<0.2	2,11	<0.1	<0.030	14,4	0,248	<0.1	4,56	<0.030	<0.1	<0.1	<0.030	<0.030	0,215	<0.1	<0.001	<0.1	<0.030	<0.1
001	<0.1	<0.2	2,07	<0.1	<0.030	17,5	0,49	<0.1	5,5	<0.030	<0.1	<0.1	<0.030	<0.030	0,376	<0.1	0,004	<0.1	<0.030	<0.1
5	<0.1	<0.2	2	<0.1	<0.030	17,5	0,642	<0.1	4,38	<0.030	<0.1	<0.1	<0.030	<0.030	0,222	<0.1	0,002	<0.1	<0.030	<0.1
78	<0.1	<0.2	1,83	<0.1	<0.030	12,8	0,443	<0.1	4,47	<0.030	<0.1	<0.1	<0.030	<0.030	0,196	<0.1	0,003	<0.1	<0.030	<0.1

Annex 3- Analytical results of soil

	Descrip	Sb	Ag	Al	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Eu	Fe	Ga	Ge	K	La	Li	Mg
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BL		< 0.1	<0.010	0.1	<0.13	<0.030	<0.1	0.036	0.835	<0.010	<0.1	<0.1	<0.030	<0.1	<0.003	0.397	<0.1	<0.2	0.09	<0.1	<0.030	0.055
CRM		0.5	0.386	143	0.91	3.82	<0.1	0.359	1190	0.14	0.2	<0.1	0.365	5.1	<0.003	131	<0.1	<0.2	57.5	0.1	0.111	60.2
242134	S-1	0.25	<0.010	26	<0.13	1.44	<0.1	0.074	206	<0.010	0.2	<0.1	0.064	0.5	<0.003	106	<0.1	<0.2	6.52	<0.1	0.044	46
242135	S-2	< 0.1	<0.010	28	<0.13	0.876	<0.1	0.047	233	<0.010	0.2	<0.1	0.057	0.2	<0.003	139	<0.1	<0.2	6.5	<0.1	0.052	67.4
242136	S-3	0.19	<0.010	29	<0.13	0.96	<0.1	0.062	286	<0.010	0.1	<0.1	0.091	0.5	<0.003	117	<0.1	<0.2	6.14	<0.1	0.05	71.3
242137	S-4	0.21	<0.010	31	<0.13	1.2	<0.1	0.064	462	<0.010	0.1	<0.1	0.052	0.7	<0.003	120	<0.1	<0.2	8.37	<0.1	0.059	120
242138	S-5	< 0.1	<0.010	30	<0.13	1.41	<0.1	0.066	317	<0.010	0.2	<0.1	0.06	0.5	<0.003	121	<0.1	<0.2	7.24	<0.1	0.057	81.3
242139	S-6	< 0.1	<0.010	30	<0.13	0.737	<0.1	0.049	149	<0.010	0.2	<0.1	0.054	0.1	<0.003	104	<0.1	<0.2	5.18	<0.1	0.042	46.6
242140	S-7	< 0.1	<0.010	36	<0.13	0.81	<0.1	0.052	78.7	<0.010	0.2	<0.1	0.059	0.2	<0.003	86.3	<0.1	<0.2	5.85	<0.1	0.047	26.4
242141	S-8	< 0.1	<0.010	34	<0.13	0.8	<0.1	0.062	47.5	<0.010	0.2	<0.1	0.055	<0.1	<0.003	83.9	<0.1	<0.2	8.51	<0.1	0.043	17.7
242142	S-9	0.13	<0.010	34	<0.13	0.78	<0.1	0.032	42.5	<0.010	0.2	<0.1	0.054	0.2	<0.003	80.9	<0.1	<0.2	6.92	<0.1	0.044	16.7
242143	S-10	< 0.1	<0.010	37	<0.13	0.843	<0.1	0.041	51.5	<0.010	0.2	<0.1	0.068	0.5	<0.003	86.6	<0.1	<0.2	7.32	<0.1	0.047	18.4
242144	S-11	0.67	<0.010	32	<0.13	14.9	<0.1	0.02	108	<0.010	0.2	<0.1	<0.030	3.3	<0.003	84.5	<0.1	<0.2	6.76	<0.1	0.043	35.9
242145	S-12	0.27	<0.010	33	<0.13	5.39	<0.1	0.042	174	<0.010	0.2	<0.1	0.051	1.1	<0.003	97.5	<0.1	<0.2	7.01	<0.1	0.054	47.4
242146	S-13	0.27	<0.010	32	<0.13	3.69	<0.1	0.09	180	<0.010	0.2	<0.1	0.049	1	<0.003	102	<0.1	<0.2	8.66	<0.1	0.049	59.1
242147	S-14	< 0.1	<0.010	34	<0.13	2.07	<0.1	0.071	134	<0.010	0.2	<0.1	0.053	0.4	<0.003	94.6	<0.1	<0.2	9.19	<0.1	0.047	38
242148	S-15	< 0.1	<0.010	33	<0.13	1.29	<0.1	0.023	50.5	<0.010	0.2	<0.1	0.054	0.6	<0.003	86.5	<0.1	<0.2	8.47	<0.1	0.042	20.8
242149	S-16	0.68	<0.010	33	<0.13	13.6	<0.1	0.061	56.3	<0.010	0.2	<0.1	<0.030	3.5	<0.003	84.7	<0.1	<0.2	6.89	<0.1	0.038	28.5
242150	S-17	0.24	<0.010	36	<0.13	5.8	<0.1	0.048	86.3	<0.010	0.2	<0.1	0.045	1.8	<0.003	94.2	<0.1	<0.2	9.24	0.1	0.047	32.5
242151	S-18	0.2	<0.010	23	<0.13	1.61	<0.1	0.048	403	<0.010	0.1	<0.1	0.036	0.4	<0.003	74.8	<0.1	<0.2	5.98	<0.1	0.044	116
242152	S-19	0.2	<0.010	24	<0.13	0.77	<0.1	0.047	470	<0.010	0.2	<0.1	0.041	0.3	<0.003	76.1	<0.1	<0.2	5.83	<0.1	0.047	155
242153	S-20	0.25	<0.010	23	<0.13	2.27	<0.1	0.063	408	<0.010	0.1	<0.1	0.05	0.6	<0.003	75	<0.1	<0.2	5.36	<0.1	0.047	110
242154	S-21	2	0.011	31	<0.13	46	<0.1	0.084	41.7	0.032	0.1	<0.1	<0.030	9.74	<0.003	85.2	<0.1	<0.2	8.56	<0.1	0.037	19.1
242155	S-22	< 0.1	<0.010	35	<0.13	1.05	<0.1	0.073	73.7	<0.010	0.2	<0.1	0.059	0.2	<0.003	99.2	<0.1	<0.2	6.44	<0.1	0.04	21.3
242156	S-23	0.16	0.014	36	<0.13	1.44	<0.1	0.012	69.1	<0.010	0.2	<0.1	0.087	1.4	<0.003	89	<0.1	<0.2	7.89	<0.1	0.042	24.8
242157	S-24	< 0.1	<0.010	40	<0.13	1.09	<0.1	0.003	42.8	<0.010	0.2	<0.1	0.078	0.8	<0.003	94.3	<0.1	<0.2	8.19	0.1	0.042	19.8
242158	S-25	< 0.1	<0.010	32	<0.13	0.825	<0.1	0.059	47.1	<0.010	0.2	<0.1	<0.030	4.1	<0.003	80.8	<0.1	<0.2	5.82	<0.1	0.042	18
242159	S-26	0.25	<0.010	30	<0.13	1.51	<0.1	0.084	328	<0.010	0.2	<0.1	0.067	0.8	<0.003	123	<0.1	<0.2	7.2	0.1	0.043	77.3
242160	S-27	0.59	<0.010	35	<0.13	1.16	<0.1	0.054	128	<0.010	0.2	<0.1	0.056	0.4	<0.003	126	<0.1	<0.2	9.57	0.1	0.037	32
242161	S-28	< 0.1	<0.010	33	<0.13	0.8	<0.1	0.022	46.9	<0.010	0.2	<0.1	0.057	0.2	<0.003	82.9	<0.1	<0.2	5.56	<0.1	0.039	15.6
242162	S-29	< 0.1	<0.010	58	<0.13	1.65	<0.1	0.061	56.5	0.011	0.2	<0.1	0.091	1.3	<0.003	114	<0.1	<0.2	13.5	0.1	0.054	22.7
242163	S-30	< 0.1	<0.010	46	<0.13	1.44	<0.1	0.066	42.2	<0.010	0.2	<0.1	0.105	1.6	<0.003	109	<0.1	<0.2	11	0.1	0.048	18.9
242164	S-31	0.11	<0.010	49	<0.13	1.34	<0.1	0.088	99	<0.010	0.2	<0.1	0.079	0.1	<0.003	96	<0.1	<0.2	24.4	0.1	0.06	32.7
242165	S-32	0.1	<0.010	49	0.15	1.35	<0.1	0.065	121	<0.010	0.2	<0.1	0.084	0.1	<0.003	92.4	<0.1	<0.2	26	<0.1	0.058	38.4
242166	S-33	< 0.1	0.011	30	<0.13	0.733	<0.1	0.017	51	<0.010	0.2	<0.1	0.053	<0.1	<0.003	91.1	<0.1	<0.2	4.59	<0.1	0.041	16
242167	S-34	< 0.1	<0.010	41	<0.13	1.09	<0.1	0.036	52.5	0.065	0.2	0.1	0.17	2.2	<0.003	93.9	<0.1	<0.2	7.02	<0.1	0.042	17.8
242168	S-35	< 0.1	<0.010	38	<0.13	0.924	<0.1	0.049	51.5	0.04	0.2	<0.1	0.383	1.8	<0.003	106	<0.1	<0.2	6.78	0.1	0.04	17.4
242169	S-36	< 0.1	<0.010	33	<0.13	0.761	<0.1	0.056	47.8	<0.010	0.2	<0.1	0.054	<0.1	<0.003	84.8	<0.1	<0.2	4.76	0.1	0.042	15.6
242170	S-37	< 0.1	<0.010	29	<0.13	0.704	<0.1	0.056	65.9	<0.010	0.2	<0.1	0.047	<0.1	<0.003	83.5	<0.1	<0.2	3.93	<0.1	0.04	16.4
242171	S-38	0.1	<0.010	29	<0.13	0.869	<0.1	<0.001	62.5	<0.010	0.2	<0.1	0.044	<0.1	<0.003	84.7	<0.1	<0.2	5.01	<0.1	0.038	14.9
242172	S-39A	51	0.113	55	<0.13	570	<0.1	0.791	26.8	0.108	<0.1	<0.1	<0.030	130	<0.003	112	<0.1	<0.2	43.4	<0.1	<0.030	117
242173	S-39B	52	0.096	52	<0.13	562	<0.1	0.644	22.4	0.126	<0.1	<0.1	<0.030	118	<0.003	138	<0.1	<0.2	45	<0.1	<0.030	106

Ga	Ge	K	La	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Sc	Sm	Sr	Th	Ti	V	Y	Zn	Zr
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
<0.1	<0.2	0.09	<0.1	<0.030	0.055	<0.030	<0.1	0.137	<0.030	<0.1	<0.1	<0.030	<0.030	<0.030	<0.1	0.004	<0.1	<0.030	0.2	<0.030
<0.1	<0.2	57.5	0.1	0.111	60.2	1.87	0.2	23.7	0.295	107	0.9	<0.030	0.034	6.77	<0.1	3.6	1.1	0.098	6.6	<0.030
<0.1	<0.2	6.52	<0.1	0.044	46	7.27	<0.1	0.67	0.097	4.2	3.2	<0.030	<0.030	0.828	<0.1	0.66	0.1	0.057	0.5	<0.030
<0.1	<0.2	6.5	<0.1	0.052	67.4	5.22	<0.1	1.15	0.1	3.6	0.4	<0.030	<0.030	0.266	<0.1	0.78	0.1	0.059	0.5	<0.030
<0.1	<0.2	6.14	<0.1	0.05	71.3	5.18	<0.1	0.801	0.121	7	0.6	<0.030	<0.030	0.369	<0.1	1.31	0.1	0.058	0.4	<0.030
<0.1	<0.2	8.37	<0.1	0.059	120	8.55	<0.1	0.929	0.111	3.8	0.98	<0.030	<0.030	0.476	<0.1	1.44	0.1	0.057	0.5	<0.030
<0.1	<0.2	7.24	<0.1	0.057	81.3	6.34	<0.1	0.816	0.11	4.4	1.7	<0.030	<0.030	1.11	<0.1	0.91	0.1	0.056	0.6	<0.030
<0.1	<0.2	5.18	<0.1	0.042	46.6	2.75	<0.1	0.626	0.084	3.3	0.2	<0.030	<0.030	0.196	<0.1	0.791	0.1	0.058	0.4	<0.030
<0.1	<0.2	5.85	<0.1	0.047	26.4	1.89	<0.1	0.888	0.0957	3.2	0.2	<0.030	<0.030	0.16	<0.1	1.07	0.1	0.061	0.3	<0.030
<0.1	<0.2	8.51	<0.1	0.043	17.7	1.93	<0.1	0.536	0.094	3.5	0.1	<0.030	<0.030	0.164	<0.1	0.699	0.1	0.061	0.3	<0.030
<0.1	<0.2	6.92	<0.1	0.044	16.7	1.78	<0.1	0.635	0.093	3.2	0.2	<0.030	<0.030	0.545	<0.1	0.859	0.1	0.058	0.4	<0.030
<0.1	<0.2	7.32	<0.1	0.047	18.4	1.93	<0.1	1.44	0.103	3.6	0.2	<0.030	<0.030	0.176	<0.1	0.982	0.1	0.061	0.5	<0.030
<0.1	<0.2	6.76	<0.1	0.043	35.9	1.85	<0.1	0.687	0.112	14.9	35.4	<0.030	<0.030	5.15	<0.1	0.696	0.1	0.056	1.5	<0.030
<0.1	<0.2	7.01	<0.1	0.054	47.4	2.5	<0.1	0.601	0.114	7	11.9	<0.030	<0.030	1.75	<0.1	0.995	0.1	0.058	0.7	<0.030
<0.1	<0.2	8.66	<0.1	0.049	59.1	2.79	<0.1	0.712	0.102	6.1	7.6	<0.030	<0.030	1.42	<0.1	0.787	0.1	0.06	0.7	<0.030
<0.1	<0.2	9.19	<0.1	0.047	38	3.64	<0.1	1.17	0.102	4.9	3.2	<0.030	<0.030	0.623	<0.1	0.822	0.1	0.061	0.5	<0.030
<0.1	<0.2	8.47	<0.1	0.042	20.8	2.12	<0.1	0.536	0.0976	4.1	1.2	<0.030	<0.030	0.334	<0.1	0.652	0.1	0.059	0.6	<0.030
<0.1	<0.2	6.89	<0.1	0.038	28.5	1.89	<0.1	0.587	0.128	13.6	34.1	<0.030	<0.030	4.99	<0.1	0.602	0.1	0.056	1.5	<0.030
<0.1	<0.2	9.24	0.1	0.047	32.5	2.44	<0.1	0.666	0.133	8.4	11.6	<0.030	<0.030	2.25	<0.1	0.934	0.1	0.066	0.9	<0.030
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Annex 4 - Analytical results of swabs

	Descrip	Sb	Ag	Al	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Eu	Fe	Ga	Ge	K	La	Li	Mg	Mn	Mo	Na
		ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug	ug
242099	FR-1	200	15	1000	<130	1570	<100	45	5670	26	<100	<100	947	500	<3	6440	<100	<200	836	<100	<30	1460	199	100	55
242100	FR-2	100	<10	200	<130	424	<100	14	1550	<10	<100	<100	34	200	<3	1110	<100	<200	1190	<100	<30	472	31	<100	97
242101	FR-3	180	<10	1000	<130	721	<100	<1	5780	49	<100	<100	117	400	<3	13300	<100	<200	634	<100	<30	1580	155	<100	59
242102	FR-4	130	<10	200	<130	137	<100	56	1470	<10	<100	<100	<30	<100	<3	617	<100	<200	145	<100	<30	314	<30	<100	52
242103	FR-5	<100	<10	100	<130	87	<100	33	1300	<10	<100	<100	<30	<100	<3	596	<100	<200	135	<100	<30	300	<30	<100	53
242104	FR-6	<100	<10	80	<130	132	<100	24	1480	<10	<100	<100	<30	<100	<3	320	<100	<200	263	<100	<30	346	<30	<100	99
242105	FR-7	<100	<10	200	<130	552	<100	15	5020	<10	<100	<100	<30	<100	<3	532	<100	<200	555	<100	<30	446	<30	<100	94
242106	FR-8	<100	<10	100	<130	219	<100	3	1660	<10	<100	<100	<30	<100	<3	536	<100	<200	195	<100	<30	450	<30	<100	75
242107	FR-9	<100	<10	100	<130	219	<100	11	1800	<10	<100	<100	<30	<100	<3	392	<100	<200	195	<100	<30	236	<30	<100	65
242108	FR-10	690	<10	5000	<130	10800	<100	41	31600	46	<100	<100	257	2500	<3	27100	<100	<200	4370	<100	<30	7720	454	<100	19
242109	FR-11	590	<10	9000	<130	4640	<100	33	4600	<10	<100	<100	<30	600	<3	1420	<100	<200	713	<100	<30	1040	<30	<100	75
242110	FR-12	<100	<10	300	<130	793	<100	28	5510	<10	<100	<100	<30	100	<3	1680	<100	<200	454	<100	<30	587	<30	<100	70
242111	FR-13	<100	<10	300	<130	766	<100	20	6070	<10	<100	<100	<30	100	<3	1060	<100	<200	454	<100	<30	540	<30	<100	55
242112	FR-14	<100	<10	100	<130	617	<100	22	1100	<10	<100	<100	<30	<100	<3	26000	<100	<200	244	<100	<30	361	310	<100	63
242113	FR-15	<100	<10	80	<130	277	<100	13	906	<10	<100	<100	<30	<100	<3	22400	<100	<200	147	<100	<30	227	230	<100	58
242114	FR-16	<100	<10	100	<130	317	<100	42	1070	<10	<100	<100	<30	<100	<3	10400	<100	<200	119	<100	<30	242	122	<100	49
242115	FR-17	23000	18	24000	<130	326000	<100	250	36200	90	<100	<100	<30	41100	<3	68600	<100	<200	32900	<100	<30	48200	1050	<100	37
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242117	FR-19	<100	<10	200	<130	1080	<100	12	1760	<10	<100	<100	<30	200	<3	663	<100	<200	258	<100	<30	793	<30	<100	64
242118	FR-20	140	<10	1000	<130	474	<100	50	9540	438	<100	<100	<30	400	<3	2810	<100	<200	2560	<100	<30	1720	521	<100	10
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242120	FR-22	1400	<10	3000	<130	16400	<100	7	16400	14	<100	<100	<30	4600	<3	9830	<100	<200	2190	<100	<30	11200	241	<100	73
242121	FR-23	<100	<10	3000	<130	1570	<100	48	13600	<10	<100	<100	<30	400	<3	7070	<100	<200	1580	<100	<30	4200	194	<100	90
242122	FR-24	<100	<10	100	<130	<30	<100	19	1020	<10	<100	<100	<30	<100	<3	162	<100	<200	267	<100	<30	196	<30	<100	67
242123	FR-25	<100	<10	1000	<130	62	<100	<1	3670	<10	<100	<100	<30	<100	<3	2480	<100	<200	529	<100	<30	935	61	<100	79
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242125	FR-27	<100	<10	300	<130	50	<100	<1	1850	<10	<100	<100	<30	<100	<3	712	<100	<200	337	<100	<30	437	<30	<100	75
242126	FR-28	<100	<10	300	<130	<30	<100	3	5660	<10	<100	<100	<30	<100	<3	376	<100	<200	90	<100	<30	332	<30	<100	38
242127	FR-29	<100	<10	300	<130	<30	<100	<1	2150	<10	<100	<100	<30	<100	<3	295	<100	<200	93	<100	<30	303	<30	<100	37
242128	FR-30	<100	<10	2000	<130	47	<100	44	5880	<10	<100	<100	<30	<100	<3	5140	<100	<200	411	<100	<30	1510	139	<100	41
242129	FR-31	<100	<10	300	<130	110	<100	26	862	<10	<100	<100	<30	<100	<3	495	<100	<200	86	<100	<30	178	<30	<100	36
242130	FR-32	<100	<10	500	<130	<30	<100	<1	735	<10	<100	<100	<30	<100	<3	425	<100	<200	407	<100	<30	160	<30	<100	47
242131	FR-33	<100	<10	200	<130	633	<100	16	909	<10	<100	<100	<30	<100	<3	643	<100	<200	87	<100	<30	249	<30	<100	38
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List of symbols/abbreviations/acronyms/initialisms

CF-18	Fighter jet in service with the Canadian Forces
cal.	Caliber
CFAD	Canadian Forces ammunition depot
CFTO	Canadian Forces technical order
EPA	Environmental protection agency
Mm	Millimeter
OB/OD	Open burning / open detonation
SAA	Small arms ammunition
US	United States
µg/g	Micrograms per gram

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Dmil E	1
DLR	1
DRDC	1
DSTL	1
DSTL-3	1
CWO CFAD Dundurn Canadian Forces Ammunition Depot Dundurn, SK S0K 1K0	3
ICIST	1
BNC	1
DTIC	1

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Disposal of surplus, obsolete, or deteriorated small arms ammunition by incineration presents the threat of heavy-metal contamination to the immediate area. The highly toxic nature of these pollutants requires that they be carefully monitored, and that steps be taken to prevent contamination altogether. The safety concerns associated with these pollutants are so serious that the United Kingdom requires stringent environmental licensing of ammunition incineration facilities, and several US states have banned the open burning of restricted materials altogether. In this context, a thorough testing of the area surrounding the small arms ammunition burning facility at CFAD Dundurn was undertaken. Groundwater, soil, and foliage from the area surrounding the burn facility were tested for the presence of heavy metals. Swab samples were taken from surfaces within the facility and these were also tested. Many of the samples showed very high levels of lead, barium, antimony, and other heavy metals. This report details the characterization of the heavy-metals contamination at CFAD Dundurn. The sampling methods are described, and the results are presented. By providing a better understanding of the nature of the problem, it is hoped that this work will help guide the Canadian Forces towards minimizing the possibly serious environmental impact of small-arms ammunition disposal.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Open Burning

OB

heavy metals

environmental impacts

contamination

incineration of ammunition

small-arms disposal

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